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A SHORT-CUT METHOD OF ESTIMATING CAPITAL STOCKS: WHEN CAN IT BE USED AND HOW WELL DOES IT WORK?

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Relatively few countries currently publish estimates of capital stocks because of the difficulty of applying the Perpetual Inventory Method. A short-cut method which we term the Steady Growth Model (SGM) can produce plausible capital stock estimates provided certain conditions are met. Starting with a database covering 146 countries we conclude that the SGM can legitimately be used to calculate capital stocks for 53 of them. The 53 include equal numbers of high-income and low-income countries. The SGM requires only data on gross fixed capital formation for the base year, information about past growth rates of real GFCF, and assumptions about rates of depreciation. Despite its apparent simplicity, we show that our SGM stock estimates compare well with official stock estimates generated by the PIM. Other tests on capital–output ratios and capital-stocks per head confirm the plausibility of stock estimates generated by SGM.

JEL Codes: E20, E22

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1. Introduction

The net capital stock is an important but much neglected component of the System of National Accounts (SNA). It is neglected because of the difficulty of estimating capital stocks using the standard, recommended, procedure known as the Perpetual Inventory Method (PIM). The purpose of this article is to describe an alternative method of estimating capital stocks which is much less data demanding than the PIM and which can generate robust estimates of the capital stock provided that the assumptions underlying this short-cut method are understood and respected.

Starting with a database of 146 countries we conclude that the short-cut method, which we term the "Steady Growth Model" (SGM), is appropriate for 53 of them. We calculate net capital stocks for these countries for 2005 and carry out a number of tests on the plausibility of our estimates. We conclude that although the SGM is not suitable for all countries it could be used by between one quarter and one third of all countries to generate net capital stock estimates for their regular national accounts. An important finding is that the method can be used by developed and developing countries alike. Of the 53 countries, 27 are non-OECD and include China, Pakistan, Bangladesh, and other large countries.

The next section explains the role of the net capital stock in the SNA. Section 3 provides an algebraic presentation of the SGM. In Section 4 we discuss the conditions in which this method can be expected to provide a reliable estimate of

*It is with great sadness that we must report that Derek Blades passed away shortly after this paper was accepted for publication in the *Review*.

a country's net capital stock. Out of 146 countries we conclude that the SGM is not suitable for estimating net stocks in 93 of them and they are excluded from the study. Section 5 explains the values we have used for the two parameters of the SGM—the rates of depreciation and the growth rate of GFCF. Section 6 presents estimates of the NCS for 53 countries, compares our SGM estimates with official PIM stock estimates, and carries out other test of their plausibility. Section 7 concludes by suggesting how the simple, one-size-fits-all, Steady Growth Model used here can be refined by individual countries to produce reliable NCS estimates for use in their national accounts.

2. The Net Capital Stock in the System of National Accounts

The Net Capital Stock (NCS) is the current market value of a country's tangible and intangible fixed assets. Tangible fixed assets consist of machinery, equipment, dwellings, other buildings, civil engineering works, and livestock that are not primarily bred for slaughter: intangible assets include computer software, mineral exploration, and literary and artistic originals. Current market values are the prices at which they could be sold in the current year, taking account of their physical condition and their remaining service lives. In effect, an asset's current market value is the present (discounted) sum of the flows of income that the purchaser hopes to realize over the remaining service lives of the assets. The NCS is a measure both of wealth and of productive potential and it features in the national accounts in both capacities.

The NCS appears in the balance sheets of the System of National Accounts (SNA), where it forms a part—usually the largest—of a country's net worth.[1] Estimates of the NCS are also required in the SNA in order to calculate consumption of fixed capital. This is particularly important for the government sector since governments' gross value added can only be obtained by adding consumption of the fixed assets they own to their compensation of employees and net operating surplus. Many countries do not estimate consumption of fixed capital on government assets or they use book-value depreciation based on historic rather than current market values: in either case they are underestimating their GDP.[2] More generally, estimates of consumption of fixed capital are required to convert gross macro-economic aggregates to their net basis. *Gross* operating surplus, *gross* value added, *gross* domestic product, *gross* national income etc. figure prominently in the SNA and in most countries' own national accounts, but this is not because they are considered more useful on a gross rather than a net basis but because so few countries have reliable estimates of their NCS with which to calculate consumption of fixed capital and thereby derive the (correct) net aggregates.

Estimation of imputed rents is another case where NCS data may be required. In many developing countries almost all dwellings are owner-occupied. The SNA suggests that rents for such dwellings should be imputed using rents actually paid

[1]The term "Net Capital Stock" is not used in the SNA: it appears as the value of "Fixed Assets" in the Balance Sheets (table 13.3 in the 2008 version of the SNA).

[2]A recent report by the African Development Bank on the reliability of GDP estimates in Africa shows that nearly a third of the 44 countries surveyed do not include consumption of fixed capital in their estimates of government value added. See African Development Bank (2013).

for similar dwellings, but very often the types of dwellings that make up most of the dwelling stock are never actually rented. The correct procedure in such cases is to estimate rents by "user-cost," which involves estimating the various costs that owners would need to take into account if they decided to rent their dwellings instead of living in them themselves. The two main costs are depreciation and operating surplus, both of which require an estimate of the current market value of the housing stock.

Last but not least, the NCS is the starting point for calculating capital services. Although capital services are not a part of the 2008 SNA (European Commission *et al.*, 2008), chapter 20 explains the conceptual and practical issues in estimating capital services and suggests that these could be shown in a supplementary table. Jorgenson and Schreyer (2013) show how SNA-consistent capital services can be introduced into the production accounts and how they can be used for productivity analysis. The United States,[3] Australia,[4] and Malaysia[5] are among several countries that now estimate capital services as a regular part of their national accounts.

In short, the Net Capital Stock is an important but much neglected component of the system of National Accounts. The reason it is neglected, of course, is that it is difficult to measure by the standard procedure—the Perpetual Inventory Method (PIM). The PIM was developed by Raymond Goldsmith[6] in the early 1950s and is now used by virtually all countries that publish official estimates of their capital stock.[7] The PIM requires an initial estimate of the capital stock—usually at some distant date in the past—to which gross fixed capital formation (GFCF) in subsequent years is added and estimated withdrawals of assets at the end of their service lives are subtracted. To obtain the net capital stock, estimates are also required of the extent to which the market prices of assets decline due to wear and tear and obsolescence. Finally, information is also required on average price inflation for each of the many different types of assets in the capital stock as each year's GFCF must be rebased to current prices. Clearly, the PIM requires a great deal of statistical information on prices and investments extending over long time periods, and few countries have such data.

At the present time, 20 of the 32 OECD member countries publish official estimates (Schreyer *et al.*, 2011) but we have only been able to find official estimates for three non-OECD countries—India, Malaysia, and Thailand—so that official NCS estimates are available for just over a tenth of the 200 or so countries and territories recognized by the United Nations. To fill the gap, non-official estimates of capital stocks have been made by the World Bank (Nehru and Dhareshwar, 1993), OECD (Schreyer *et al.*, 2003), and by numerous academic researchers including Harberger (1978), Maddison (1994), and Wu (2012). The purpose of this article is to show that plausible estimates of the NCS can be derived by a short-cut method which requires only information on gross fixed capital

[3]See Fraumeni *et al.* (2006) and Jorgenson and Landefeld (2006).
[4]See Australian Bureau of Statistics (2000).
[5]See Department of Statistics Malaysia (2012).
[6]See Goldsmith (1951).
[7]The OECD capital stock manual (OECD 2009) reports that Japan and Korea use surveys of enterprises to obtain data on the value of their capital stocks. All other OECD countries use some variation of the PIM.

formation (GFCF) together with knowledge of, or assumptions about, the rate of depreciation and the long-term growth of real GFCF. We term this method the "steady growth model" (SGM): other authors have described it as the "steady state model", but as we explain below, "steady growth" rather than "steady state" better captures the essential features of the method.

3. The Steady Growth Model

The SGM appears to have been devised by Harberger (1978) to obtain estimates of capital stocks in a number of developing countries. Subsequently it has been used to estimate an initial capital stock for use in a PIM model—see, for example, Nehru and Dhareshwar (1993) and King and Levine (1994). The description of the SGM below is taken (with some modifications) from Annex C of the OECD capital stock manual (OECD, 2009).

The net capital stock at the beginning of year 0 (K^{t0}) is approximately equal to the sum of the market values of the assets (I^t) that were installed in earlier years and that are still in use. If the market values of these assets decline each year at a constant rate (δ) through obsolescence and through wear and tear, equation (1) expresses this relationship.[8]

$$K^{t0} \approx I^{t0-1} + I^{t0-2}(1-\delta) + I^{t0-3}(1-\delta)^2 + \ldots.. \tag{1}$$

Suppose now that GFCF grows each year in real terms by a constant rate θ so that $I^{0t-2} = I^{0t-1}/(1+\theta)$, and $I^{0t-3} = I^{0t-1}/(1+\theta)^2$ . . . .

Then the net capital stock at the beginning of the benchmark year can be written as:

$$K^{t0} \approx I^{t0-1}\left\{1+[(1-\delta)/(1+\theta)]+[(1-\delta)/(1+\theta)]^2 \ldots\right\}. \tag{2}$$

Equation (2) is a geometric series with $\frac{1-\delta}{1+\theta}$ as the common ratio and its sum to n is therefore:

$$K^{t0} \approx I^{t0-1}\left(1-\left(\frac{1-\delta}{1+\theta}\right)^n\right)\Big/\left(1-\frac{1-\delta}{1+\theta}\right). \tag{3}$$

The common ratio $\frac{1-\delta}{1+\theta}$ must lie between 0 and 1 if δ and θ are both positive numbers and if δ lies between 0 and 1. Consequently, as $n \to \infty$ the term $\left(\frac{1-\delta}{1+\theta}\right)^n$ in (3) approaches zero[9] and equation (3) becomes:

[8]This is an approximation to K^{t0} because I^{t0-1} will also have depreciated by the beginning of year 0 except in the unlikely event that all I^{t0-1} occurred on the last day of the year.

[9]Given the average δ and θ values used here, the term $\left(\frac{1-\delta}{1+\theta}\right)^n$ becomes negligible even at small values of n. For example, with $n = 10$ it has already reduced to 1.11E-6 and with $n = 20$ it falls to 1.22E-12.

$$(4)\qquad K^{t0} \approx \frac{I^{t0-1}}{1-\dfrac{1-\delta}{1+\theta}} = \frac{I^{t0-1}}{\dfrac{1+\theta}{1+\theta}-\dfrac{1-\delta}{1+\theta}} = \frac{I^{t0-1}}{\dfrac{1+\theta-1+\delta}{1+\theta}} = \frac{I^{t0-1}(1+\theta)}{\theta+\delta} = \frac{I^{t0}}{\theta+\delta}.$$

In words, equation (4) shows that the net capital stock at the beginning of the year 0 (K^{t0}) is approximately equal to the GFCF of the year 0 (I^{t0}) divided by the sum of the rate of depreciation (δ) and the growth rate of real GFCF (θ).

Other authors have derived the SGM from theoretical considerations about the relationship between capital and output. King and Levine (1994) derive their "steady-state" estimates of the capital stock as follows:

> *The steady-state estimate of the capital stock is based on the assumption that the capital–output ratio is constant, which implies that* $dK_t/K_t = dY_t/Y_t$*. Consequently, since* $dK_t = I_t - \delta K_t$*, then* $dK_t/K_t = I_t/K_t - \delta$*, where* I_t *is gross investment and* δ *is capital's depreciation rate. We also define the growth rate* $y_t = dY_t/Y_t = I_t/K_t - \delta$*. Letting i equal the investment rate,* I_t/Y_t *the steady-state capital–output ratio for country j is:*

$$(5)\qquad Kj = i_j/[\delta + y_j]$$

In equation (5) Kj is the capital–output ratio. Multiplying by output Yj to obtain the equation for the capital stock, gives us:

$$(6)\qquad K_j = I_j/(\delta + y_j)$$

where K_j and I_j are, respectively, the net capital stock and the GFCF of country j. δ is the depreciation rate and y_j is the equivalent of θ in equation (4).

The two differences between (4) and (6) are that (6) is shown as an equality while (4) is shown as an approximation, and that θ in (4) is the growth rate of real GFCF while y_j in (6) is the growth rate of real "output"—by which we assume that King and Levine mean GDP.

King and Levine describe (6) as the "steady state" estimate of the capital–output ratio because they start from the proposition that each country's capital–output ratio remains constant over the estimation period. The derivation of the SGM ending with (4) above requires no assumption about capital–output ratios but it does require the assumptions that real GFCF is growing at a constant rate over time.[10] For that reason we prefer to call it the "Steady Growth Model." The plausibility of the growth assumption is examined below.

[10]Note however, that while the SGM requires no explicit assumption about the capital–output ratio it is clear that SGM implicitly assumes that GDP is also growing at a steady rate in order to support the steady growth of GFCF. The SGM and the steady state models can therefore be seen as essentially identical.

4. Conditions for Using the SGM

The reliability of the capital stock estimate derived by the SGM clearly depends on the validity of the various assumptions about δ and θ.

As regards the depreciation rate (δ) two assumptions are involved. First, the SGM assumes that the depreciation rate is constant over time. This is the assumption made by most, though not all countries, for their official capital stock estimates. Maddison (1994) notes that Germany and the U.K. both assume declining asset lives, and Schreyer *et al*. (2003) also assume declining asset lives over time in their standardized estimates for 19 OECD countries.[11]

Next, the model assumes that depreciation occurs at a constant rate, meaning that market values decline by the same percentage each year. This is usually referred to as geometric depreciation. In their official stock statistics many OECD countries in fact make a different assumption, such as straight-line depreciation which means that market values fall by the same amount (i.e., at an increasing rate) each year. Nevertheless geometric depreciation rates are used by an increasing number of countries for their official estimates, including the United States. In explaining why the U.S. Bureau of Economic Analysis (BEA) decided to adopt geometric depreciation instead of the straight-line depreciation previously used, Fraumeni (1997) notes that for most types of assets geometric depreciation closely approximates observed declines in second-hand asset prices. Actually, BEA decided to move to geometric depreciation following publication of a large scale empirical investigation of depreciation patterns in the United States by Hulten and Wykoff (1981). The authors concluded that "We have argued . . . that depreciation can indeed be measured using a variety of approaches. We have also shown that many of these studies obtain the result that depreciation is accelerated relative to straight-line and can be reasonably well approximated by geometric (or declining balance) depreciation."

The geometric depreciation rate for a particular type of asset is written as d/L, where d is the declining balance rate and is most often set between 1 and 2. L is the average number of years that the asset is expected to remain in use. We explain below the d and L values used here.

As regards the growth rate (θ), it is assumed that real growth of GDP has been constant over the lifetimes of the assets currently in the stock. Note that growth must have been regular in the past and the level of GFCF in year 0 must be in line with past rates of growth. Both of these assumptions are tested in the next section.

4.1. *Growth Rates of GFCF: Are They Constant?*

The World Bank's World Development Indicators (WDI) database includes GFCF at constant prices for 166 countries including most of the 146 in our ICP database. We have used these data to fit exponential curves of the form $Y = Ae^{bX}$, where Y is constant price GFCF in local currency units (LCU), X is time, and A

[11]Kamps (2004) also finds that implicit depreciation rates from official PIM stock estimates increase over time in most OECD countries, but this is most likely because in recent years their asset stocks include more short-lived assets and not because they are assuming declining service lives for given types of assets.

and b are constants. The version of WDI used here covers the period 1960 to 2011 although few countries have data covering the whole period. We have first rejected countries that had data for less than 20 years on the grounds that this is the minimum period required to fit a reliable curve. Next we have rejected countries for which the R^2 of the exponential function is less than 0.7. These are both arbitrary rules and others may prefer different thresh olds.

Figure 1 shows the exponential curves fitted to real GFCF for six countries.

- The first two—China and Australia—have high R^2 values for the exponential curve and are clearly countries where real GFCF has indeed been growing at a constant rate.
- The next two are borderline cases. For Ecuador, R^2 was just over the 0.7 cut-off and so was accepted; Madagascar's R^2 was just under 0.7 and was therefore eliminated from the study.
- The last two are countries where real GFCF has clearly not been growing at constant rates and both have been eliminated. The strong cyclical pattern of investment in Uruguay is particularly striking.

This test has eliminated 77 of the initial 146, leaving 69 countries that have reported 20 or more years of data and for which an exponential curve can be fitted to their real GFCF with an R^2 of at least 0.7. The attrition rate was particularly high for the 11 CIS countries. Investment fell catastrophically after the break-up of the Soviet Union and has been erratic since then. The attrition rate was much lower for European countries where fiscal and monetary policies are often directed towards maintaining steady growth of investment (and GDP). This was also partly true of Asia, but in Africa, South America, and West Asia real GFCF is often highly cyclical or erratic. Investment is sensitive to the business cycle. For example, GFCF will usually be lower than its long-term trend value when an economy emerges from recession status and fuller use is made of idle capacity. Cyclical movements of this kind may partly explain the volatility of GFCF growth in countries excluded from the study.

Of the 46 OECD-European countries, 34 were retained at this stage, as were 12 of 23 Asian countries, 18 of 48 African countries, four of 10 in South America, and one of the 11 CIS countries. None of the 11 West Asian countries were retained: either too few data points were available or their R^2 values were too low. Appendix Table A gives the R^2 values and the estimated long-run growth rates of real GFCF for the 69 countries retained at this stage.

4.2. *Was GFCF in 2005 Exceptional: Too High or Too Low?*

Even though growth of real GFCF may have been broadly steady in the past, GFCF may have been exceptionally high or low in 2005. If so, this would produce an unreliable stock estimate. Harberger (1978) suggested that for this reason it may be better to use an average of several years GFCF rather than a single year, but this is not possible here as we only have GFCF broken down by asset type for 2005. An alternative is to compare the actual 2005 real GFCF with the trend value derived from the exponential curve.[12] Appendix Table B shows the estimated trend levels

[12]A similar procedure was used by Nehru and Dhareshwar (1993). They describe it as "modified Harberger."

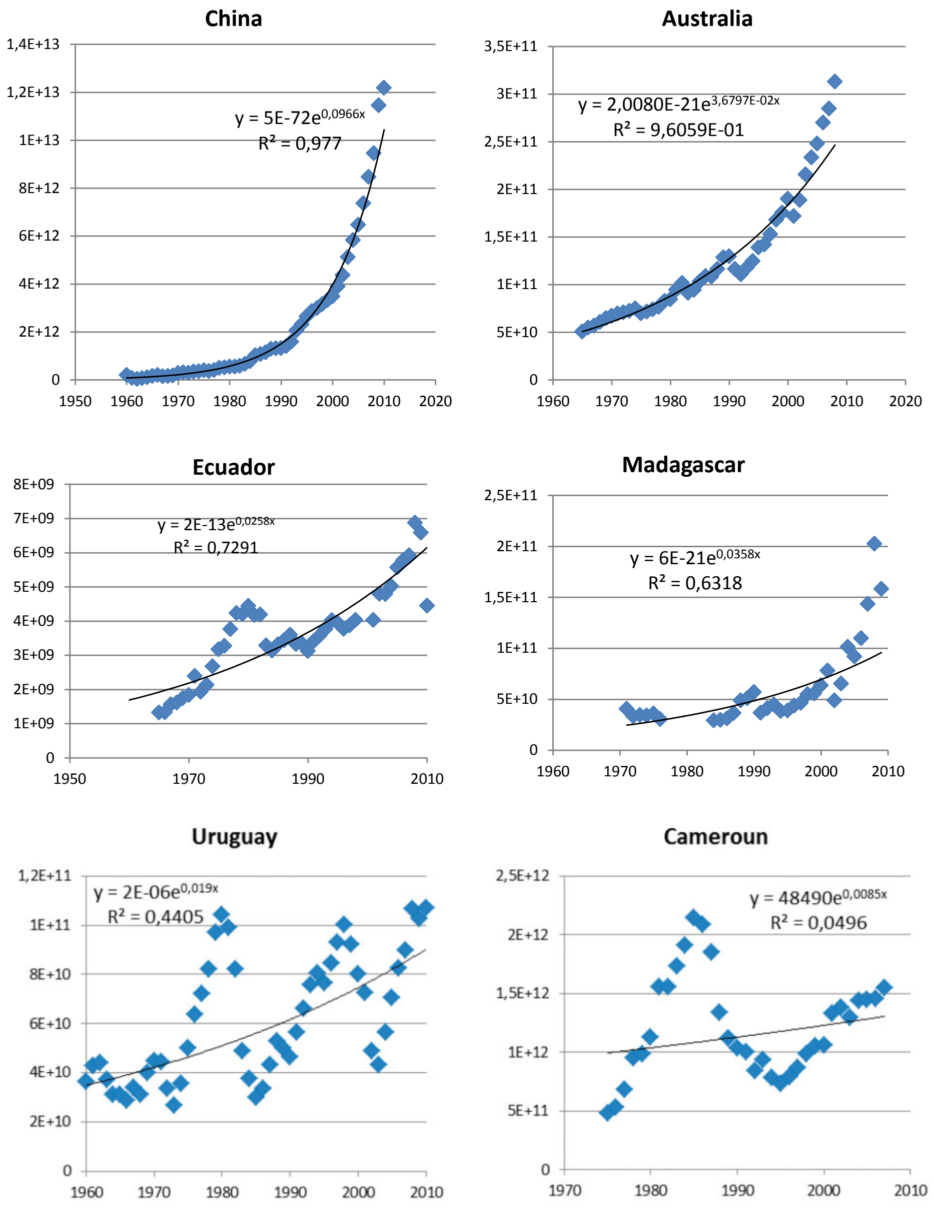

Figure 1. Examples of Exponential Curves Fitted to Real GFCF

of real GFCF compared with the actual levels for 2005. For 14 countries the actual levels of real GFCF were 20 percent higher or lower than the trend values. These 14 countries were eliminated: this is again an arbitrary decision. Azerbaijan and Sri Lanka were also dropped at this stage because they did not report real GFCF to the WDI for 2005.

The GFCFs of the remaining 53 countries, as reported for the 2005 ICP, were then adjusted by the ratios of the trend to actual real GFCF as shown in Appendix Table B. Here is an example of the adjustment for Australia:

- In Figure 1 the exponential curve for Australia is shown as $Y = 2.0080\text{E-}21e^{0.036797X}$.
- With $X = 2005$, Y (the trend level of real GFCF in 2005) is therefore 2.2087E+11.
- The WDI database gives the actual real GFCF as 2.4799E+11 for that year. The ratio of the trend to actual real GFCF is 0.891 as shown in Appendix Table B. This means that Australia's real GFCF in 2005 was about 11 percent above trend.
- For the ICP 2005 Australia reported GFCF of 244,300 mn Aus$. Australia's adjusted GFCF is therefore 244,300 · 0.891 = 217,580 mn Aus$. Australia's GFCF for 2005 at 2005 prices has now been brought down to the long-term trend level.

Note that the same adjustment factor is applied to all five different types of assets. It would obviously be better to calculate trend levels for each asset type separately, but this is the best we can do with the available data.

5. Estimating the Net Capital Stock for 53 Countries

We now have a group of 53 countries which meet the two principle criteria for applying the short-cut method—namely their past growth rates are broadly steady and their (adjusted) GFCF in 2005 is in line with past patterns of growth. The next tasks are to decide on the values for the depreciation rate (δ) and the real growth rate of GFCF (θ). The 2005 round of the International Comparison Programme covered 146 countries. Each was required to provide estimates of expenditures on GFCF broken down by type of asset. We have used these data as the starting point for estimating net capital stocks using the SGM.

5.1. *Depreciation Rates*

Our ICP database breaks down GFCF into six asset types: "metal products and equipment," "transport equipment," "residential buildings," "non-residential buildings," "civil engineering," and "other products." Clearly these six asset types will have very different service lives and hence different rates of depreciation. Table 1 shows service lives used by nine countries. There is some measure of agreement on the lives of ships and of railway rolling stock, but counties are using very different service lives for most other types of assets. The last column shows the service lives we have adopted for these six asset types. They are not averages: they are round numbers that we believe are not implausible given the different service lives used by the nine countries. Our reasoning is as follows:

- "Metal products and equipment" is a large component of the capital stock and includes general purpose machinery such as electric motors, machine tools, lifting and handling equipment, as well as special purpose equipment for construction, power generation, communications, etc. It also includes

TABLE 1
Examples of Asset Service Lives Used in Nine Countries

	Belgium	Canada	Finland	Germany	India	Italy	Malaysia	Netherlands	U.S.A.	Used here
Metal products and equipment	15–25	12–35	5–27		8–33	18	5–20	14–33	16–18	20
Transport equipment: of which						10				10
Cars and trucks	10	8–11	7–12		10		10–14	4–9		
Railway rolling stock		25			28			28	28	
Ships	25	27					20	25	27	
Aircraft					15			16	12–20	
Residential buildings	34–40			14–59		35–65	70	75	20–80	50
Non-residential buildings			35–50		32–50			31–41	16–48	50
Civil engineering works		10–57	25–50		60			55	40	40
Other products:										15
Livestock							16			
Development of plantations							30			
Software								3	3–5	
Mineral exploration							68	40		

Sources: India: Kumar *et al*. (1987). Malaysia: Department of Statistics Malaysia (2011). Other countries: OECD (2009).

computers and the 5 year lives shown in Table 1 for Finland and Malaysia are for computers and related equipment. Country estimates range from 5 to 33. We have used 20 years.

- In the case of "transport equipment," we assume that most of the stock consists of road vehicles and 10 years seems reasonable.
- We have assumed that "residential" and "non-residential buildings" have the same service lives—50 years.
- "Civil engineering" includes roads, dams and bridges, electric power transmission systems, sewage, street lighting, and water systems. Lives used by the nine countries range from 10 to 60 but are usually lower than for buildings. We have used 40 years.
- "Other products" is a particularly heterogeneous group. It consists of plantation, orchard, and vineyard development; change in stocks of breeding animals, draught animals, dairy cattle, animals raised for wool clippings; land improvement including dams and dikes which are part of flood control and irrigation projects; mineral exploration; computer software that a producer expects to use in production for more than one year; acquisition of entertainment, literary, or artistic originals; and other intangible fixed assets. We have assumed that orchards and plantations with lives of perhaps 25 years and computer software with lives of perhaps 5 years will be the largest components in most countries and have adopted 15 years as the service life for the group as a whole.

The depreciation term is written as d/L where L is the service life and d is the declining balance rate. If d is set at 1, annual depreciation of a particular asset is one *Lth* of the previous year's market value of that asset. Commercial accountants typically use double declining depreciation where d is set at 2 so that asset values decline twice as fast—at 2 *Lths* per year. Various d values have been used for capital stock estimates:

- Katz and Herman (1997) gives the declining balance rates used by the Bureau of Economic Analysis (BEA) for the United States' capital stock estimates. These range from highs of 2.2664 for government-owned vehicles and 2.1832 for computers to lows of 0.9747 for industrial buildings and 0.8892 for office buildings. For the large majority of assets however, d is set at 1.6500.
- For the Canadian productivity accounts, Statistics Canada (2007) explains that two declining balance rates are used: 2.1 for building construction and 2.3 for all other types of assets except software.
- Eurostat (2001) recommends that for estimating stocks of dwellings ". . . geometric depreciation can be used with a declining balance rate of 1.6. . . . A declining balance rate of 1.6 is recommended because simulations have shown that with this rate, total user costs for a stock of assets are most similar to total user costs obtained using the straight-line method and an approximately normal distribution of service lives around the mean life."

For simplicity we have set d at 1.6 for all types of assets. This is the Eurostat recommendation for residential buildings and is close to the 1.65 used for most types of machinery and equipment by the United States BEA. Depreciation rates for each asset type are therefore as shown in Table 2.

TABLE 2
Service Lives and Depreciation Rates by Type of Asset

	Service Life in Years (L)	Depreciation Rate (1.6/L)
Metal products and equipment	20	0.080
Transport equipment	10	0.160
Residential buildings	50	0.032
Non-residential buildings	50	0.032
Civil engineering works	40	0.040
Other products	15	0.107

5.2. *Growth Rate of Real GFCF*

Long-term growth rates for real GFCF can be obtained from the exponential curves we have already fitted to the real GFCF taken from WDI. These growth rates are derived as $e^b - 1$ and are shown in Appendix Table A. These have been used for all asset types except residential dwellings for which we have used population growth rates from the WDI. We have used the geometric average of population growth rates over the 50-year period 1960 to 2010. The population growth rates are shown in Appendix Table C(a).

6. Net Capital Stocks for 53 Countries: How Plausible Are These Estimates?

We now have all the information required to proceed with our calculations of the net capital stock derived as GFCF/($\theta + \delta$). Specifically:

- Appendix Table D shows GFCF for each of the six types of assets. These are taken from the ICP database but have been adjusted to their trend levels as explained above. They are in LCUs.
- Growth rates (θ) for residential buildings are assumed to equal population growth rates (see Appendix Table C) while for all other assets the long term growth rates of real GFCF have been used (see Appendix Table A).
- Depreciation rates (δ) calculated as d/L for each asset type are shown in Table 2.

Our estimates of the net capital stocks for the 53 countries are shown in Appendix Table E. Like the GFCF data from which they are derived they are in LCUs.

6.1. *Comparison with Official Estimates*

Seventeen of the 53 countries have published official estimates of the net capital stock for 2005 in 2005 prices. Table 3 compares these with the SGM capital stock estimates in Appendix Table E. Figure 2 shows the ratios of the short-cut to official estimates. A ratio of over 1.0 means that the SGM estimate exceeds the official estimate: ratios below 1.0 mean that the SGM estimates are lower than the official figures.

Table 3 shows the average and the standard deviation of the ratios—1.008 and 0.161, respectively. For these 17 countries the short-cut method has produced

TABLE 3

Comparison between Official and SGM Estimates of the Net Capital Stock for 17 Countries: 2005 in LCUs

	Official NCS	SGM NCS	Ratio: Official/SGM
Australia	2,799,118	3,139,000	0.90
Austria	825,930	896,085	0.92
Belgium	913,034	808,473	1.13
Canada	3,794,321	2,878,550	1.34
Finland	503,546	423,298	1.19
France	5,475,297	5,210,390	1.06
Germany	7,283,595	6,892,500	1.06
Hungary	67,877,183	84,106,791	0.81
India	75,602,745	8,718,310	0.87
Italy	4,495,893	4,586,719	0.96
Luxembourg	65,007	63,798	1.02
Netherlands	1,561,366	1,651,478	0.94
Norway	4,962,660	4,670,288	1.06
Slovenia	19,937,197	23,392,982	0.85
Switzerland	1,521,683	1,146,285	1.33
Thailand	20,250,665	22,661,433	0.89
United States	30,631,389	37,581,378	0.81
Average			1.008
Standard deviation			0.161

Source: The official estimates for Thailand are from Office of the National Economic and Social Development Board (2007) and for India are from Central Statistical Office (2013). For all other countries the official estimates are from OECD (2010).

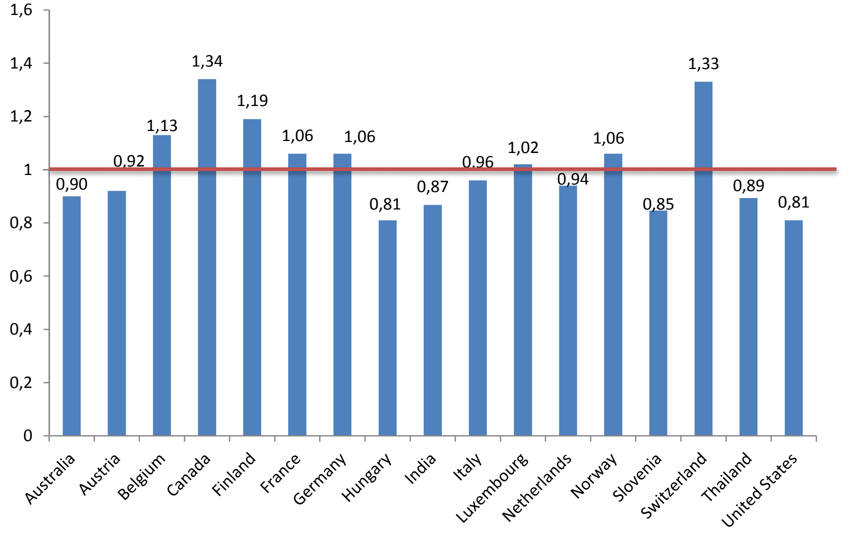

Figure 2. Ratios of SGM to Official estimates of Net Capital Stock in 2005

almost unbiased estimates of the net capital stock: on average they are only 0.8 percent above the true figure, where "true" refers to the PIM estimates made by national statistical offices. The standard deviation shows that in two-thirds of cases the short-cut estimate are within ±16 percent of the true figure. Actually for six of the 17 countries the short-cut estimates are within ±6 percent of the official estimate and within ±10 percent for nine of them. The "true" figures are themselves subject to quite wide margins of error and most statistical offices would probably be pleased if their PIM estimates of the stock lie within ±16 percent of the actual (unknowable) capital stock. The results for Canada and the United States are rather disappointing as these countries are generally thought to have good stock estimates but, overall, Table 3 and Figure 2 can be taken as providing assurance that the short-cut method is generating plausible estimates of the net capital stocks for most countries.

6.2. *Capital–Output Ratios*

The capital–output ratios (CORs) for the 53 countries are given in Appendix Table F: they are calculated as NCS/GDP. Figure 3 shows that most CORs lie between 2 and 3 which is consistent with other COR estimates. The ranking of countries also appears plausible. Countries with low CORs are mostly low income countries and those with higher CORs are mostly richer countries. In view of this it may seem surprising that China has the highest COR, but this is in line with what other researchers have found. Low returns to captal in China (implying high CORs) have long puzzled researchers. See, for example, Wu (2012), who estimates China's average COR for 2000–2009 at 4.07.

6.3. *Are CORs Positively Correlated with Levels of Development?*

In his influential article "Capital Accumulation and Economic Growth," Nicholas Kaldor (1961) asserted as a "stylized fact," that in capitalist counties there is a "near identity of the percentage rates of growth of production and of the capital stock." This was disputed by Maddison (1994), who calculated long-run CORs for six OECD countries and found rapid growth of capital stocks and rising CORs. King and Levine (1994) agree with Maddison: "we find that capital–output ratios are strongly positively associated with the level of economic development." They calculated NCS by both the SGM and the PIM for 105 countries using GFCF data from the Penn World Tables, and concluded that in the 1980s CORs ranged from an average of 1.40 for 35 African countries to an average of 2.51 for 24 OECD countries.

Our calculations provide some support for the proposition of positive correlation between economic development and CORs. For 26 OECD countries the average COR is 2.89 as against 2.50 for 27 non-OECD countries. Figure 4 correlates per capita GDP with CORs for the 53 countries. The linear trend shows positive correlation although the R^2 value suggests that differences in per capita GDP account for only about 10 percent of the variance in CORs.

6.4. *Comparing our CORs with Other Estimates*

Table 4 compares our SGM COR estimates with estimates by King and Levine (1994) and Wu (2012). There are some encouraging similarities between

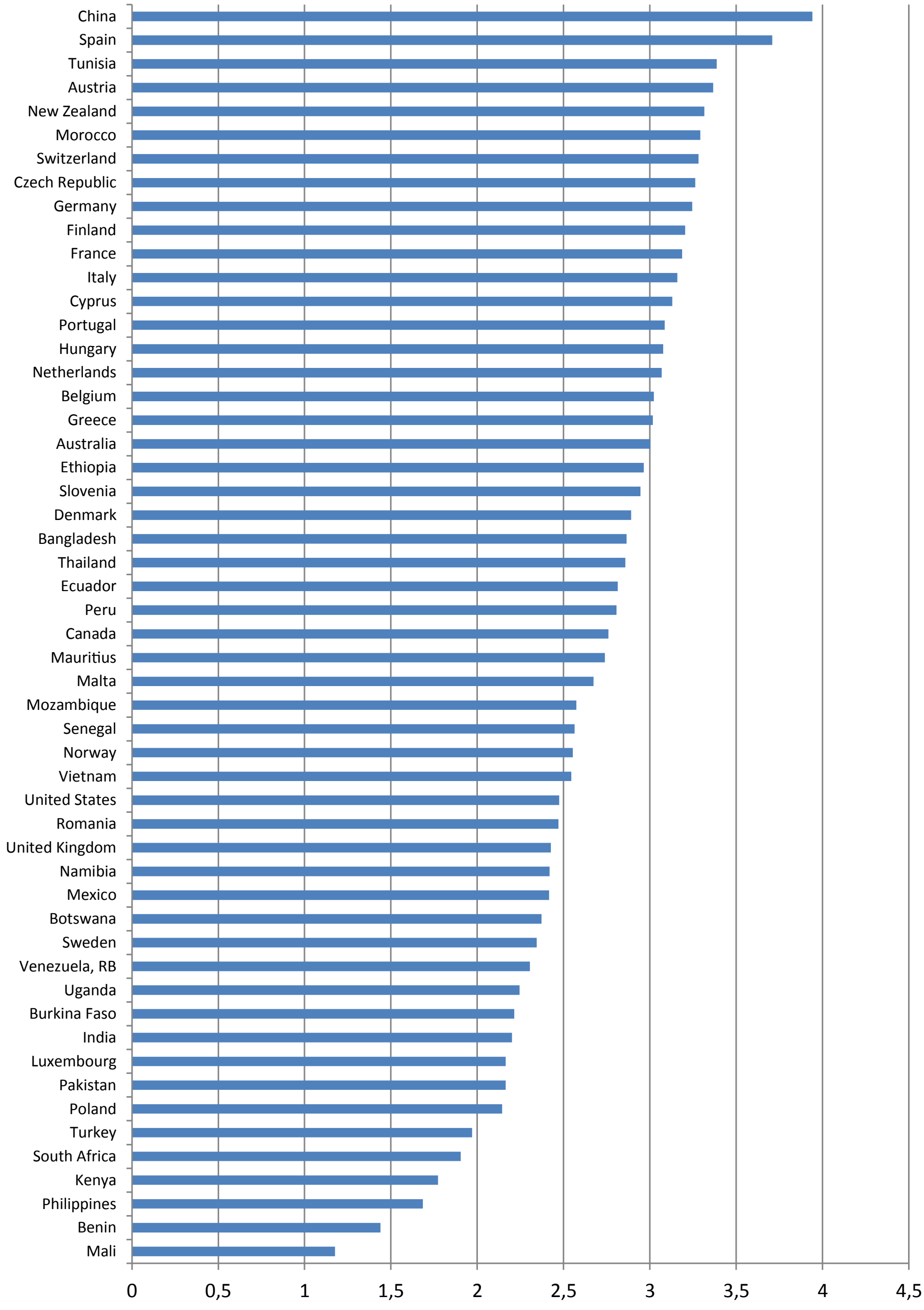

Figure 3. Capital–Output Ratios

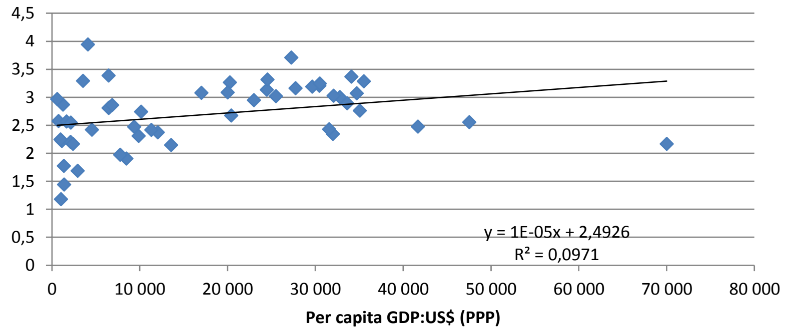

Figure 4. Capital–Output Ratios and per capita GDP: 2005

TABLE 4

Capital–Output Ratios: Other Authors Compared with Blades

Country/Group	King and Levine (mid-1980s)	Wu (2000–2009)	Blades (2005)
OECD	2.59		2.89
Non-oil, non-OECD	1.61		2.89
Africa	1.49		2.36
China		4.07	3.94
Germany		3.01	3.24
India		2.17	2.20
Thailand		2.84	2.86
United States		2.27	2.48

Notes: King and Levine's capital stocks are derived from a PIM with the initial stock estimated by steady-state. Wu's stock estimates are derived by PIM. For the Blades estimates, "Non-oil, non-OECD" includes all non-OECD countries in our sample except Venezuela.

Wu's estimates and our own, but there are also large differences between our CORs and King and Levine's for Africa and for non-oil non-OECD. There could be several explanations for this:

- King and Levine's estimates refer to the mid-1980s while ours are 20 years later: economic growth during those 20 years can be expected to have raised CORs for low income countries. Second, our estimates refer only to countries where real GFCF has been growing steadily in the long-term. King and Levine rejected only countries to which Summers and Heston (1991) had given low gradings for data quality, so their estimates include many countries which we have rejected as unsuitable for the SGM. And finally, we have used different depreciation and growth rates. For example, King and Levine set δ at 0.070 for all countries. Our δ values range from 0.032 (buildings) to 0.160 (transport equipment). Weighted by asset shares in total GFCF the average δ is 0.066. Our lower depreciation rate will generate higher NCS estimates, hence higher K/Y ratios.
- Wu's estimates are much closer to ours probably because they are averages for 2000 to 2009 and so much closer in time to our 2005 estimates. Nevertheless, there are differences in methodology and data sources. For China,

Wu has used revised GDP estimates from Maddison and Wu (2008), rather than official figures, and data for all countries are in constant 1990 prices.

6.5. *Net Capital Stocks and Gross Domestic Product*

In accounting terms, GDP is the sum of consumption expenditure, GFCF, net increase in inventories, net acquisition of valuables, and net exports. The last three net items will usually sum to zero over long periods so that GDP can be seen essentially as consisting of GFCF and consumption expenditure. As the NCS is the accumulation of GFCF less depreciation, we can expect a positive correlation between GDP and the NCS.

Figure 5 shows per capita NCS and per capita GDP for the 53 countries. The data are shown in 2005 US$ converted using PPPs. Per capita GDP in PPP is taken directly from World Bank (2008). The six components of the NCS have each been converted from LCUs to US$ using the asset-specific PPPs in Appendix Table C(b), and total NCS is obtained as their sum.

In Figure 5, Luxembourg is top of the ranking whether per capita GDP or per capita NCS is used. Most other countries do, however, change rank, although usually by only one or two positions. Larger changes include China, which rises from 39th for per capita GDP to 29th for per capita NCS, Finland, which rises from 14th for per capita GDP to 4th for per capita NCS, and the United States, which falls from 3rd for per capita GDP to 5th for per capita NCS.

In general, however, countries that have high (low) GDP also have high (low) NCS. Figure 6 shows the correlation between the two measures. Both GDP and NCS are shown per capita. This is done for presentational purposes. The GDPs and NCS of large countries are many times those of poorer countries so that charts of total NCS and total GDP are difficult to read, but of course the relationship between the two is the same whether on a total or per capita basis. The high R^2 of 0.93 lends reassurance that our SGM-derived estimates of the NCS are behaving as expected.

7. Conclusions: Improving the Steady Growth Model for Individual Countries

The SGM has produced estimates of net capital stocks that are broadly consistent with official PIM estimates. Other tests involving capital output ratios and the per capita stocks also suggest that our SGM generates plausible estimates of the net capital stock provided that GFCF has been growing steadily in the past and that GFCF in the base year is in line with the trend.

These encouraging and important results were obtained using a one-size-fits-all estimation model: a standard asset-breakdown was used for all countries; assets in all countries were assumed to have the same service lives and depreciation rates; GFCF in all assets except dwellings was assumed to be identical to the growth of total GFCF; and GFCF in dwellings was assumed to grow at the same rate as each country's total population. These various assumptions can certainly be improved at the individual country level. For example:

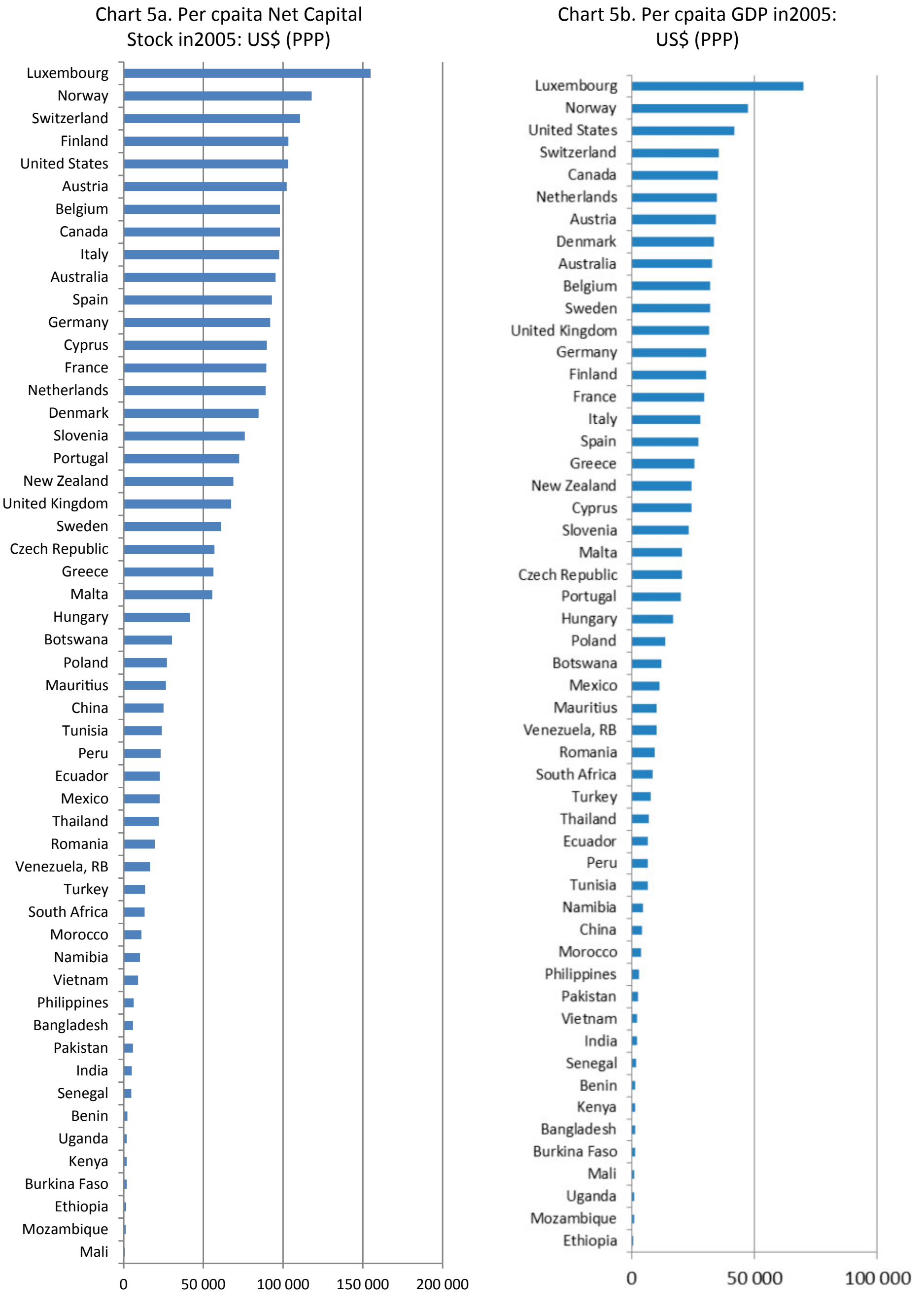

Figure 5. Per Capita Net Capital Stock and Per Capita GDP in 2005: US$ (PPP)

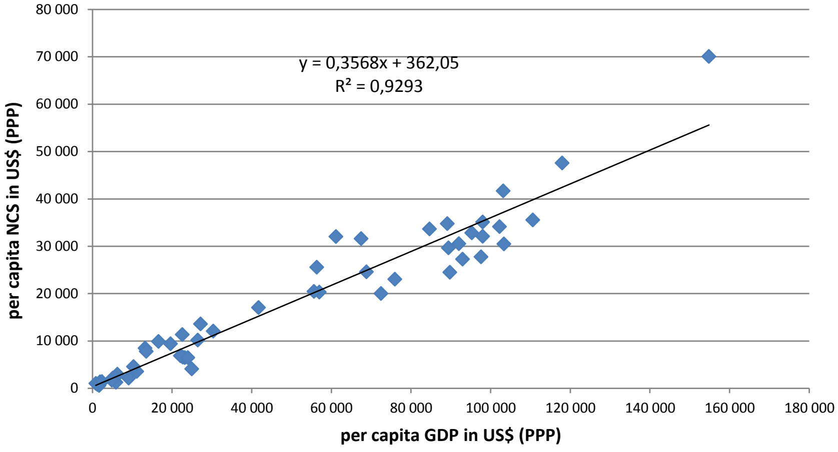

Figure 6. Correlation between Per Capita NCS and Per Capita GDP in 2005: US$ (PPP)

- The six-way asset breakdown used here for GFCF can be improved by identifying particular types of machinery and equipment that are important in particular countries, such as oil extraction and refining plant, or mining and construction equipment. Transport equipment can be broken down into road, rail, water, and air transport; civil engineering could be broken down into roads, sewage and water systems, electricity transmission networks, airports and seaports; and for "other products" it would be useful to distinguish separately software, plantation and orchard development, and increase in herds of draught and milk animals.
- Real growth rates should be used for each asset type distinguished rather than using, as here, a single overall GFCF growth rate. The assumption that GFCF in residential construction is identical to the population growth rate can also be improved: it is likely that over time the average size of dwellings increases, and demographic/social changes may mean that over time more dwellings are required to house a population of a given size.
- We have assumed that service lives and depreciation rates are the same for all countries, but Table 1 shows that countries have their own estimates of service lives that are often very different from those used here. It seems clear that service lives do differ from country to country, and if a country has its own information on actual service lives these should be used. In particular, it seems clear that in many developing countries fixed assets are overused by comparison with the same assets in more developed countries. Transport equipment is a case in point: in developing countries both passenger and freight transport vehicles may be kept in service for 20 years or more, while our one-size-fits-all model assumes a service life of 10 years for all transport equipment.
- Finally, in counties where GFCF is volatile from year to year, it may be better to take a moving average of three or more years rather than the GFCF of a single year.

Implementing these various improvements to our one-size-fits-all model will require additional effort but the Steady Growth Model will still be much easier to apply than the laborious Perpetual Inventory Method. And the evidence presented here suggests that many countries could use it to fill what is currently an important lacuna in their national accounts.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table A: R^2 values and long-run annual growth rates of real GFCF (69 countries)
Table B: Estimated and Actual Real GFCF in 2005: LCUs (67 countries)
Table C(a): GDP in LCUs: Population levels and growth rates: per capita GDP In 2005 (PPP)
Table C(b): Purchasing Power Parities: 2005 USA = 1.00
Table D: GFCF in 2005 adjusted to trend level: in LCU
Table E: Net Capital Stocks: 2005 in LCUs (53 countries)
Table F: Capital output ratios (CORs): Total and Non-Residential (53 countries)